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(71) Applicant:
Sun Microsystems, Inc.
Palo Alto, California 94303 (US)

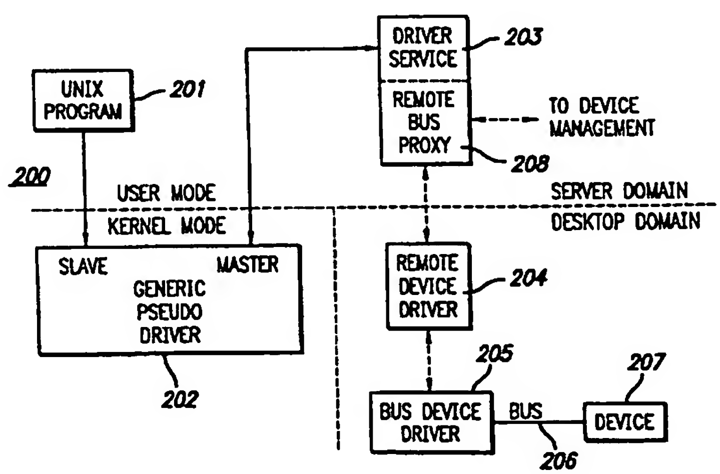
(72) Inventor: Ruberg, Alan T.
Foster City, California 94404 (US)

(74) Representative:
Goddar, Heinz J., Dr.
FORRESTER & BOEHMERT
Franz-Joseph-Strasse 38
80801 München (DE)

(54) Virtual device driver

(57) A pseudo device driver is provided for use by an operation system in a virtual desktop computing environment. The driver has two ports, a master port that is opened by the driver application and a slave port accessed by a program. The two ports provide the functionality necessary for supporting the remote device on the terminal. When a program accesses a device coupled to the terminal, the program opens the pseudo device driver's slave port and proceeds as if the device were coupled to a local bus.

FIG. 2



EP 1 049 012 A2

Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] This invention relates to the field of computer systems.

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2. BACKGROUND ART

[0003] Computer systems often include additional devices used to provide additional functionality. These devices, often called "peripheral" devices, can include keyboards, printers, scanners, network interface and graphics cards, modems, monitors, cameras, and sound input devices. Generally, a device driver is used to control the peripheral device. In some network environments, the traditional device driver may not be appropriate for an attached device. This problem can be understood by a review of peripheral devices.

[0004] Peripheral devices are often connected to a computer system through an expansion bus. An expansion bus allows the processor of a computer system (via software running on the processor), main memory, and other hardware associated with a computer system to control peripheral hardware devices external to the computer system. An expansion bus consists of conductors for data and control signals, along with hardware support logic chips and possibly firmware. There are a variety of expansion buses such as ISA (Industry Standard Architecture), PCI (Peripheral Component Interconnect), S-Bus, VME bus, etc. Each expansion bus defines a certain protocol by which devices that are on the bus are accessed.

[0005] A device driver is software used to control a peripheral device that is coupled with the computer system on the bus. A device driver is a program that controls a particular type of device that is attached to your computer. There are device drivers for printers, displays, CD-ROM readers, diskette drives, and so on. Many device drivers are built into an operating system. New device drivers are needed for devices for which the operating system does not already have drivers. A device driver converts the more general input/output instructions of the operating system to messages that the device type can understand. In many computer system, device drivers exist as a dynamic link library (DLL) file. Since misprogramming of a peripheral on a bus can cause loss of service or system failure, it is customary for device drivers to be run in a protected, or kernel, mode.

[0006] Figure 1 illustrates symbolically the interrelation of devices, device drivers, and application programs. Devices, such as devices A and B, communicate through a bus (such as an expansion bus) to system software. The system software includes device drivers (device driver A and device driver B, respectively) implemented in the system software kernel. Applications can access the devices through the system software kernel and the appropriate device drivers.

[0007] A problem can arise where, in some network environments, a peripheral device may not be coupled directly to the computer system through the bus, but rather through a network connection. In those cases, traditional device drivers may not operate correctly to permit operation of the peripheral device, however, the only interface that is provided by the operation system is through a device driver.

SUMMARY OF THE INVENTION

[0008] A pseudo device driver is provided for use by an operation system in a virtual desktop computing environment. Where traditional device drivers do not operate correctly to permit operation of a peripheral device, and the only interface that is provided is through a device driver, the present invention provides a virtual device driver to act as an adapter to couple an application to the peripheral device. The pseudo device driver has two ports, a master port that is opened by the driver application and a slave port accessed by a program. The two ports provide the functionality necessary for supporting the remote device on the terminal. When a program accesses a device coupled to the terminal, the program opens the pseudo device driver's slave port and proceeds as if the device were coupled to a local bus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Figure 1 illustrates the relationship of devices, device drivers, and application programs.

Figure 2 illustrates an embodiment of the present invention.

Figure 3 illustrates the virtual desktop environment of the present invention.

Figure 4 is a block diagram of one embodiment of an HID of the present invention.

Figure 5 illustrates a single chip HID embodiment of the present invention.

Figure 6 illustrates an embodiment of the invention.

Figure 7 illustrates the pseudo device driver of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] The invention is a method and apparatus for providing a virtual device driver. In the following description, numerous specific details are set forth to provide a more thorough description of embodiments of the invention. It will be apparent, however, to one skilled in the art, that the invention may be practiced without these specific details. In other instances, well known features have not been described in detail so as not to obscure the invention.

Virtual Desktop System Architecture

[0011] One environment in which the present invention may be applied is in a virtual desktop system. One example of such a computer system is described in U. S. Patent Application number 09/063,335 filed April 20, 1998 and entitled "Method and Apparatus for Providing a Virtual Desktop System Architecture". In such a system, there is provided a central office metaphor to computing, where features and functions are provided by one or more servers and communicated to an appliance terminal through a network. Data providers are defined as "services" and are provided by one or more processing resources. The services communicate to display terminals through a network, such as Ethernet. The terminals are configured to display data, and to send keyboard, cursor, audio, and video data through the network to the processing server. Functionality is partitioned so that databases, server and graphical user interface functions are provided by the services, and human interface functionality is provided by the terminal. Communication with the terminals from various services is accomplished by converting disparate output to a common protocol. Appropriate drivers are provided for each service to allow protocol conversion. Multiple terminals are coupled to the network. Users can enable their unique session at any one of the terminals by logging in such as by inserting a "smart card" into a card reader. Removing the card disables the session. Re-inserting the card into the same or any other terminal re-enables the session.

[0012] In the computer system described above, the interfaces for peripheral devices coupled to the human interface terminal appear over a network protocol and do not involve operating system device drivers in the traditional sense. Therefore, existing device driver software does not operate correctly.

[0013] In this system the functionality of the system is partitioned between a display and input device, and data sources or services. The display and input device is a human interface device (HID). The partitioning of this system is such that state and computation functions have been removed from the HID and reside on data sources or services. In one embodiment of the invention, one or more services communicate with one or more HIDs through some interconnect fabric, such as a network. An example of such a system is illustrated in Figure 3. Referring to Figure 3, the system consists of computational service providers 300 communicating data through interconnect fabric 301 to HIDs 302.

Computational Service Providers

[0014] In the HID system, the computational power and state maintenance is found in the service providers, or services. The services are not tied to a specific computer, but may be distributed over one or more traditional desktop systems such as described in connection with Figure 1, or with traditional servers. One computer may have one or more services, or a service may be implemented by one or more computers. The service provides computation, state, and data to the HIDs and the service is under the control of a common authority or manager. In Figure 3, the services are found on computers 310, 311, 312, 313, and 314. It is important to note that the central data source can also be providing data that comes from outside of the central data source, such as for example, the internet or world wide web. The data source could also be broadcast entities such as those that broadcast data such as television or radio signals.

[0015] Examples of services include X11/Unix services, archived or live audio or video services, Windows NT service, Java™ program execution service, and others. A service herein is a process that provides output data and responds to user requests and input.

[0016] It is the responsibility of the service to handle communications with the HID that is currently being used to access the given service. This involves taking the output from the computational service and converting it to a standard protocol for the HID. This data protocol conversion is handled in one embodiment of the invention by a middleware layer, such as the X11 server, the Microsoft Windows interface, a video format transcoder, the OpenGL interface, or a variant of the java.awt.graphics class) within the service producer machine. The service machine handles the translation to and from the virtual desktop architecture wire protocol.

[0017] In an embodiment of the invention, each service is provided by a computing device optimized for its performance. For example, an Enterprise class machine could be used to provide X11/Unix service, a Sun MediaCenter could be used to provide video service, a Hydra based NT machine could provide applet program execution service.

[0018] The service producing computer systems connect directly to the HIDs through the interconnect fabric. It is also possible for the service producer to be a proxy for another device providing the computational service, such as a database computer in a three tiered architecture, where the proxy computer might only generate queries and execute user interface code.

Interconnection Fabric

[0019] In the invention, the interconnection fabric is any of multiple suitable communication paths for carrying data between the services and the HIDs. In one embodiment the interconnect fabric is a local area network implemented as an Ethernet network. Any other local network may also be utilized. The invention also contemplates the use of wide area networks, the internet, the world wide web, and others. The interconnect fabric may be implemented with a physical medium such as a wire or fiber optic cable, or it may be implemented in a wireless environment.

[0020] In one embodiment of the invention, the interconnect fabric provides actively managed, low-latency, high-bandwidth communications between the HID and the services being accessed. One embodiment contemplates a single-level, switched network, with cooperative (as opposed to competing) network traffic. Dedicated or shared communications interconnects may be used in the present invention.

Human Interface Devices

[0021] The HID is the means by which users access the computational services provided by the services. Figure 3 illustrates HIDs 321, 322, and 323. A HID consists of a display 326, a keyboard 324, mouse 325, and audio speakers 327. The HID includes the electronics need to interface these devices to the interconnection fabric and to transmit to and receive data from the services.

[0022] A block diagram of the HID is illustrated in Figure 4. The components of the HID are coupled internally to a PCI bus 412. A network control block 402 communicates to the interconnect fabric, such as an ethernet, through line 414. An audio codec 403 receives audio data on interface 416 and is coupled to block 402. USB data communication is provided on lines 413 to USB controller 401.

[0023] An embedded processor 404 may be, for example, a Sparc2ep with coupled flash memory 405 and DRAM 406. The USB controller 401, network controller 402 and embedded processor 404 are all coupled to the PCI bus 412. Also coupled to the PCI 412 is the video controller 409. The video controller 409 may be for example, and ATI Rage128 frame buffer controller (or any other suitable controller) that provides SVGA output on line 415. NTSC or PAL data is provided into the video controller through video decoder 410. A smartcard interface 408 may also be coupled to the video controller 409.

[0024] Alternatively, the HID can be implemented using a single chip solution as illustrated in Figure 5. The single chip solution includes the necessary processing capability implemented via CPU 501 and graphics renderer 505. Chip memory 507 is provided, along with video controller/interface 506. A universal serial bus (USB) controller 502 is provided to permit communication to a mouse, keyboard and other local devices attached to the HID. A sound controller 503 and interconnect interface 504 are also provided. The video interface shares memory 507 with the CPU 501 and graphics renderer 505. The software used in this embodiment may reside locally in non volatile memory or it can be loaded through the interconnection interface when the device is powered.

Pseudo Device Driver

[0025] In the virtual desktop environment described above, the system kernel cannot communicate with a peripheral directly over a bus. Instead, communication occurs through the network fabric to the HID, where the peripheral is connected. The present invention provides a means for communication between the kernel software and the peripheral via a pseudo device driver, remote device driver, and driver service/proxy mechanism.

[0026] The pseudo device driver provides an interprocess conduit form a legacy application which expects a kernel interface (e.g. read, write, open, close, ioctl in Unix) to a user-mode service which then communicates with an HID over an interconnect. This enables the legacy application to access devices which are not directly connected to the computer (server) on which it is running, but still act as if they are directly connected.

[0027] The pseudo device driver has special function for managing master and slave ports. These include multiplexing and tracking multiple requesting services, providing multiple families of slave ports, correlating services connected to master ports with slave ports, and creating the correct number of slave device nodes for each service connected to a master port. The pseudo device driver identifies each created slave node to the service on the master port sufficiently for the service to communicate slave identity to prospective applications. The pseudo device driver further notifies the master port when a slave port is opened.

[0028] The pseudo device driver has functions that include routing standard data transfers such as those from read and write between the service and the application, maintaining data integrity and order, including any synchronized data transfer semantics. The pseudo device driver converts device control commands (e.g. Unix ioctl) into protocol which are passed on to the service. Likewise, converting protocol from he service into responses to control commands. The pseudo device

driver maintains data integrity and ordering, including synchronized device control semantics.

[0029] The pseudo device driver optionally caches any state which is set by control commands or by standard operation of the device for rapid access by the application. It initializes any optional cached state, implements any open semantics that are required by the particular device interface (such as device port cloning or exclusive use) and implements any closed semantics that are required by the particular device interface (such as waiting for the device to finish its operation, and timeout on hang). The pseudo device driver propagates standard error handling based on direction from the service.

[0030] An embodiment of the present invention is illustrated in Figure 2. A peripheral device, such as device 207, is coupled to an HID in the desktop domain via a bus 206. The bus is coupled to a bus device driver at the desktop domain. The bus device driver communicates commands from the device to a generic remote device driver 204, also at the desktop domain.

[0031] The remote device driver 204 communicates to the server domain through the network fabric to driver service 203/remote bus proxy 208. The remote device driver is a standard device driver hosted by the bus device driver. The remote device driver, however, emulates a number of device drivers for the purposes of remote access, so it is likely to own all but a few of the devices on the HID. As a result, the remote device driver is responsible for keeping track of which remote driver services go to which devices that are exposed at the bus device driver. Additionally, the remote device driver picks up configuration events from the bus device driver and reports them for possible connection to a driver service. Finally, the remote device driver has the ability to permit and deny device and unit access by driver services. It maintains filters of interested services that are directly connected to it as well as a generic filter to report devices that might not be session-specific. The remote bus proxy 208 is an equivalent interface to the bus device driver that can be used in a similar fashion by multiple services.

[0032] Service/proxy 203/208 communicates to a master port of generic pseudo device driver 202 in the system software kernel. An application program, such as Unix program 201, can use the driver via a slave port of the pseudo driver 202.

[0033] In operation, the pseudo device driver 202 is resident in kernel software, but is not connected. A driver service 203 is a service which is capable of remotely controlling one or more devices. Driver services control their associated devices using an appropriate bus specific protocol. The driver service uses the remote bus proxy 208 to help structure itself with respect to a session and handling the device protocol.

[0034] The remote bus proxy 208 converts function calls into protocol for the remote device driver 204. Since the remote bus proxy 208 handles the remote device driver, its interfaces are necessarily bus-specific. It is responsible for sending requests and data to the remote device driver. It also provides call-back routines for connect and disconnect events, and any other asynchronous event that the bus protocol dictates (e.g. USB interrupts).

[0035] The driver service 203 is aware of the master port of the pseudo driver 202. When the driver service 203 is initiated, it interfaces with the pseudo driver 202 via the master port and commands the pseudo driver to create a slave port. The driver service is then able to report the location of the slave port to the application program 201.

[0036] When the program 201 needs to access the peripheral 207, it provides commands to the slave port of the pseudo driver 202. The pseudo driver 202 interprets the commands and provides them, via the master port, to driver service 203. Driver service 203, using its associated remote bus proxy 208, communicates with the appropriate remote device driver 204 at the HID of interest. The remote device driver 204 interprets the message from service/proxy 203/208 and sends commands to bus device driver 205. Bus device driver 205 then controls the device 207 with signals on bus 206.

[0037] The pseudo device driver is system kernel software that provides the interfaces that a device driver has for obtaining system resources (e.g. objects for accessing memory, including registers) and for otherwise doing any operation on the system. The pseudo device driver does not control the bus 206.

[0038] An example of the present invention is illustrated in Figure 6. Figure 6 shows the use of a pseudo device driver in connection with an audio device. A user starts a utaudio service via, for example, a UNIX program 601. There may be multiple users on the network using utaudio service. Each utaudio service creates a utaudio daemon service 603 that opens a master port on the pseudo device driver 602. The master port creates two slaves ports for each master port accessed by a daemon service 603. The slave ports are identified by a temporary file /tmp/SUNWut/dev/utaudio/#. The pseudo device driver maps each daemon to its appropriate temporary file. The UNIX program accesses the daemon driver via the assigned slave ports and routes requests and data to and from the daemon via the slave/master ports and eventually to audio management 604 in the desktop domain.

[0039] The pseudo device driver provides an interprocess communication mechanism to convert kernel mode interfaces into messages that go to a user mode service. The pseudo device driver maps between a standard program interface and a device service interface that performs device functions. The pseudo device driver fulfills the need for a supervisor mode interface where one is currently not needed except for the fact that it a program interface expects one to be available.

[0040] Figure 7 illustrates the pseudo device driver of the present invention. Slave port management 701

manages the connection of the applications to the slave ports. Master clone port manager 702 manages the connection of services to the master ports of the pseudo device driver. The pseudo device driver provides port creation, ope, close, open, close semantics, data transfer, cached states and device control between the slave port management and master clone port management.

[0041] The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

Claims

1. An apparatus for providing one or more applications with access to one or more devices, comprising;

    a pseudo device driver having one or more slave ports and one or more master ports, said slave port configured to provide an interface to one or more applications, said pseudo device driver providing an interprocess conduit between said one or more slave ports and said one or more master ports;
    one or more driver services coupled to said one or more master ports, said one or more driver services coupled to one or more devices.

2. The apparatus of claim 1, wherein said pseudo device driver is resident within the system software kernel, said interface comprising a kernel interface.

3. The apparatus of claim 2 wherein said one or more driver services are user-mode services.

4. The apparatus of claim 1, wherein said pseudo device driver is configured to multiplex and track multiple driver services on said one or more master ports.

5. The apparatus of claim 1, wherein said pseudo device driver is further configured to correlate said one or more services coupled to said one or more master ports with associated slave ports.

6. The apparatus of claim 1, wherein said pseudo device driver is further configured to perform conversion of device control commands received via said one or more slave ports into service protocol for transmission to said one or more driver services.

7. The apparatus of claim 6, wherein said pseudo device driver is further configured to perform conversion of service protocol from said one or more driver services into responses to control commands for transmission lo said one or more slave ports.

8. The apparatus of claim 1, wherein said pseudo device driver is configured to cache driver state.

9. The apparatus of claim 1, wherein said one or more devices comprise one or more remote devices, and wherein said one or more driver services are coupled to said one or more remote devices via one or more remote device drivers accessed by said one or more driver services across a network.

10. A method for providing an application with access to a device, comprising:

    receiving, via a slave port of a pseudo device driver, device commands from said application;
    interpreting said device commands and providing the interpreted commands in a service protocol to a driver service via a master port of said pseudo device driver; and
    controlling said device via said driver service.

11. The method of claim 10, further comprising caching driver state within said pseudo device driver.

12. The method of claim 10, further comprising providing a kernel interface to said application via said slave port.

13. The method of claim 10, further comprising said driver service communicating over a network to a remote device driver to control a remote device.

14. The method of claim 10, further comprising:

    initiating said driver service;
    said driver service interfacing with said pseudo device driver via said master port;
    said driver service commanding said pseudo device driver to create said slave port;
    said driver service reporting the location of said slave port to said application.

15. A computer program product comprising:

    a computer usable medium having computer readable program code embodied therein for causing a computer to provide an application with access to a device, said computer readable program configured to cause said computer to perform the steps of:
    receiving, via a slave port of a pseudo device driver, device commands from said application;
    interpreting said device commands and providing the interpreted commands in a service protocol to a driver service via a master port of said pseudo device driver; and
    controlling said device via said driver service.

16. The computer program product of claim 15, wherein said computer readable program code is further configured lo cause said computer to cache driver state within said pseudo device driver.

17. The computer program product of claim 15, further comprising computer readable program code configured to cause said computer to provide a kernel interface to said application via said slave port.

18. The computer program product of claim 15, further comprising computer readable program code configured to cause said computer to communicate over a network via said driver service to a remote device driver to control a remote device.

19. The computer program product of claim 15, further comprising compuler readable program code configured to cause said computer to perform the steps of:

   initiating said driver service;
   said driver service interfacing with said pseudo device driver via said master port;
   said driver service commanding said pseudo device driver to create said slave port;
   said driver service reporting the location of said slave port to said application.

FIG. 1

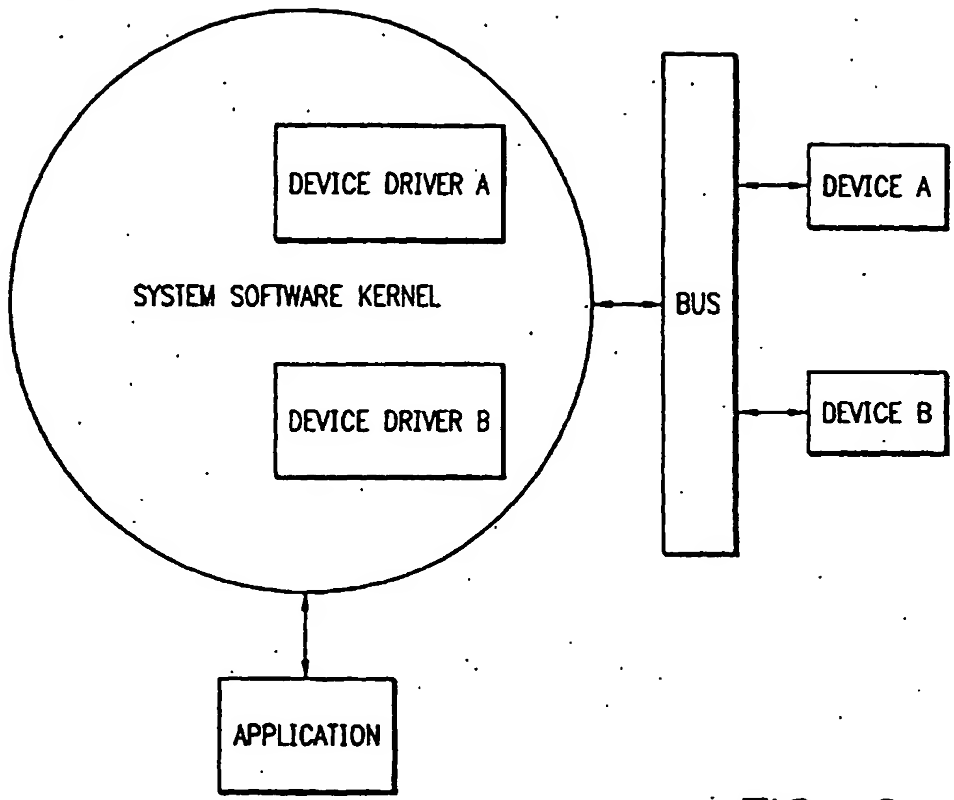
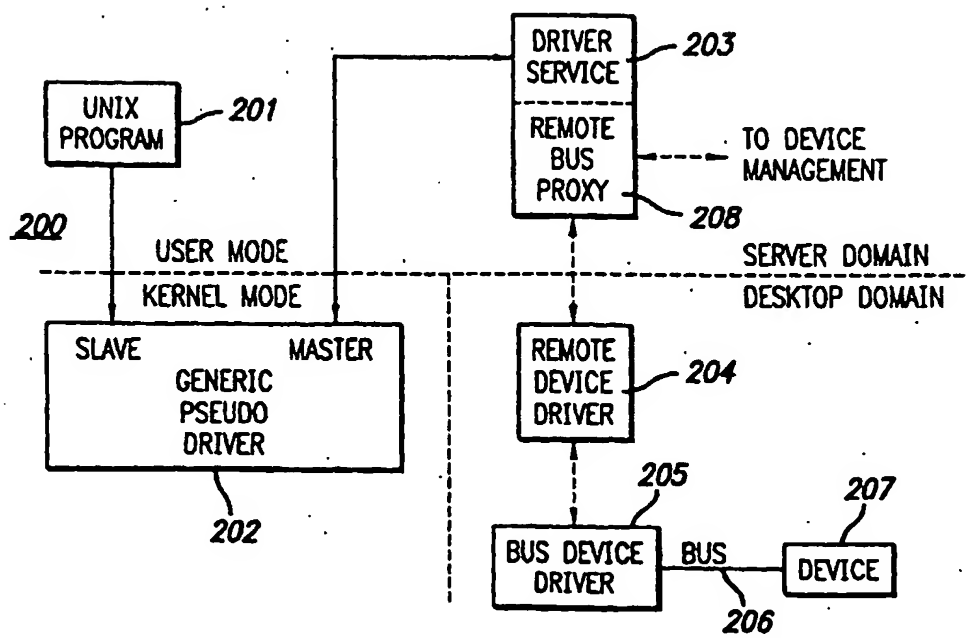

DEVICE DRIVER A
SYSTEM SOFTWARE KERNEL
DEVICE DRIVER B
BUS
DEVICE A
DEVICE B
APPLICATION

FIG. 2


DRIVER SERVICE
203
UNIX PROGRAM
201
REMOTE BUS PROXY
TO DEVICE MANAGEMENT
208
200
USER MODE
KERNEL MODE
SERVER DOMAIN
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205
207
BUS DEVICE DRIVER
BUS
DEVICE
206

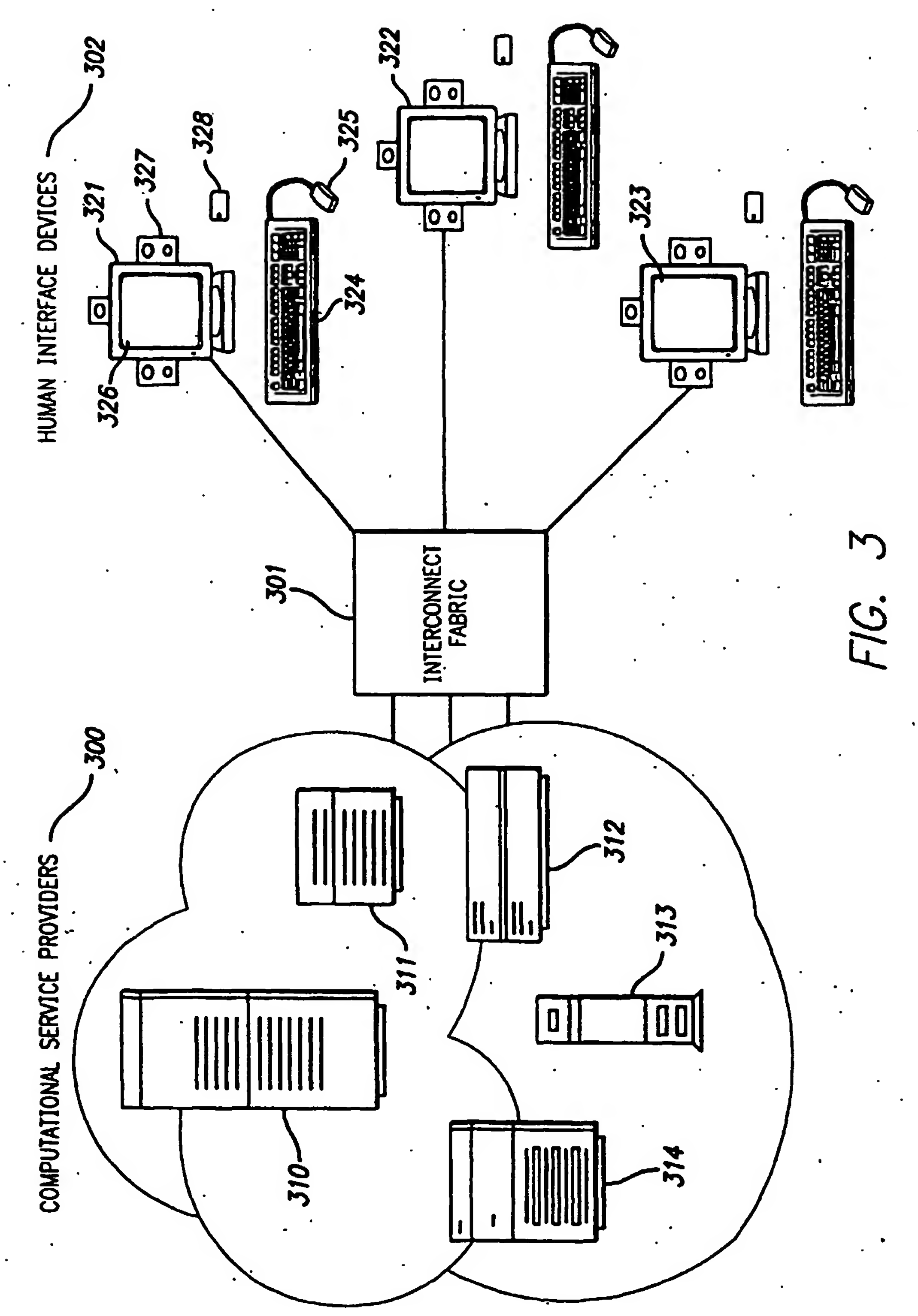
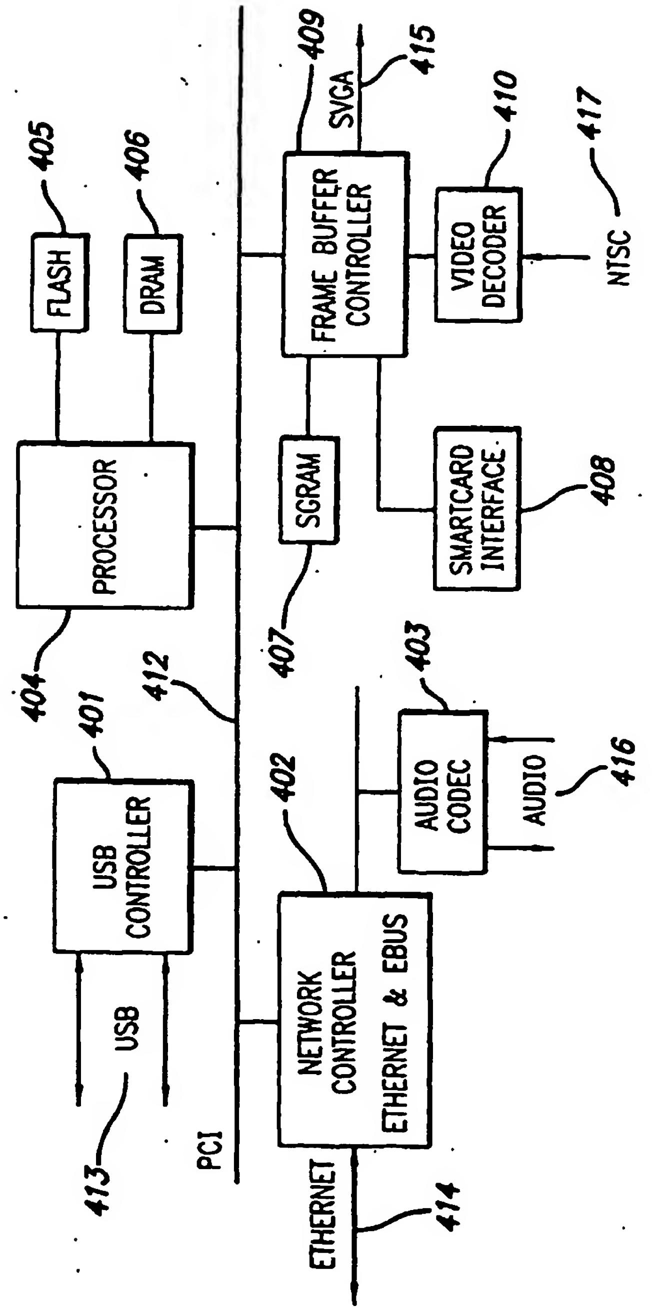

HUMAN INTERFACE DEVICES
302
321
327
328
325
322
326
324
323
301
INTERCONNECT FABRIC
COMPUTATIONAL SERVICE PROVIDERS
300
311
312
313
310
314

FIG. 3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USB
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402
ETHERNET
414
AUDIO
CODEC
403
AUDIO
416
SGRAM
407
FRAME BUFFER
CONTROLLER
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SVGA
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DECODER
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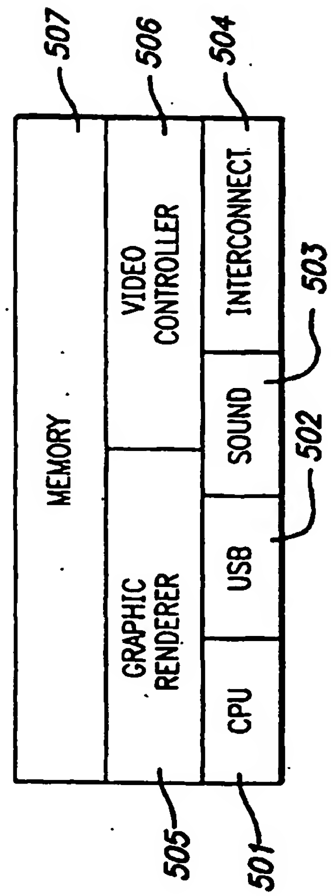
NTSC
417

FIG. 4

FIG. 5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506
CPU
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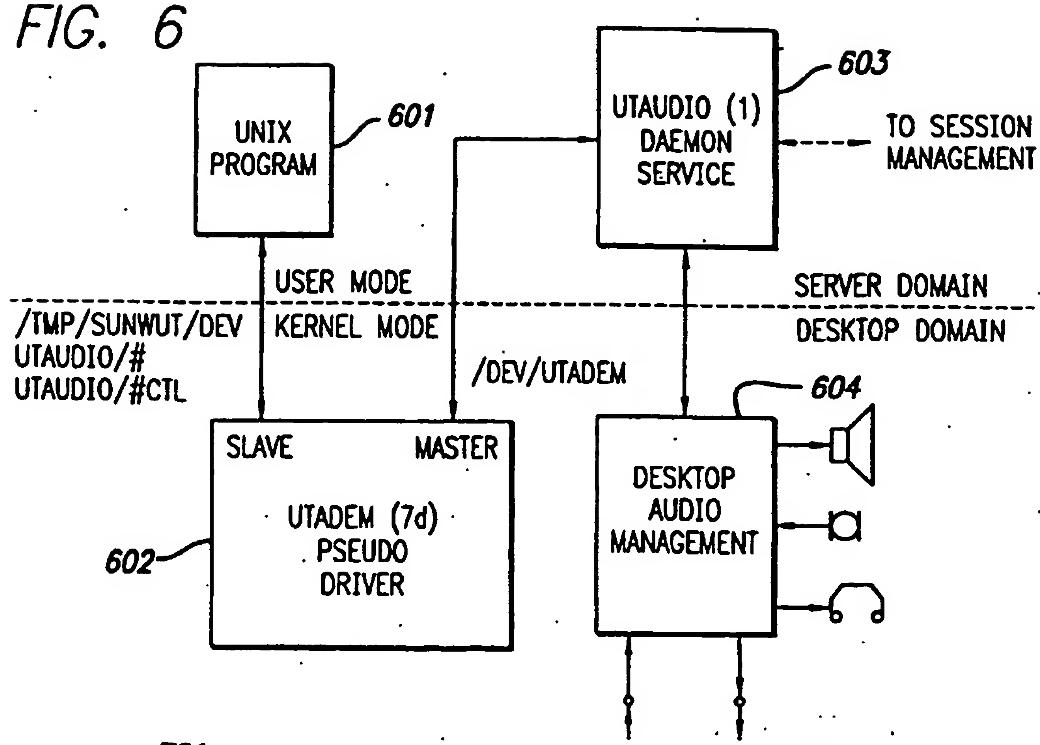
USB
502
SOUND
503
INTERCONNECT
504

FIG. 6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603
TO SESSION MANAGEMENT
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KERNEL MODE
SERVER DOMAIN
DESKTOP DOMAIN
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UTAUDIO/#
UTAUDIO/#CTL
/DEV/UTADEM
604
SLAVE
MASTER
UTADEM (7d) PSEUDO DRIVER
602
DESKTOP AUDIO MANAGEMENT

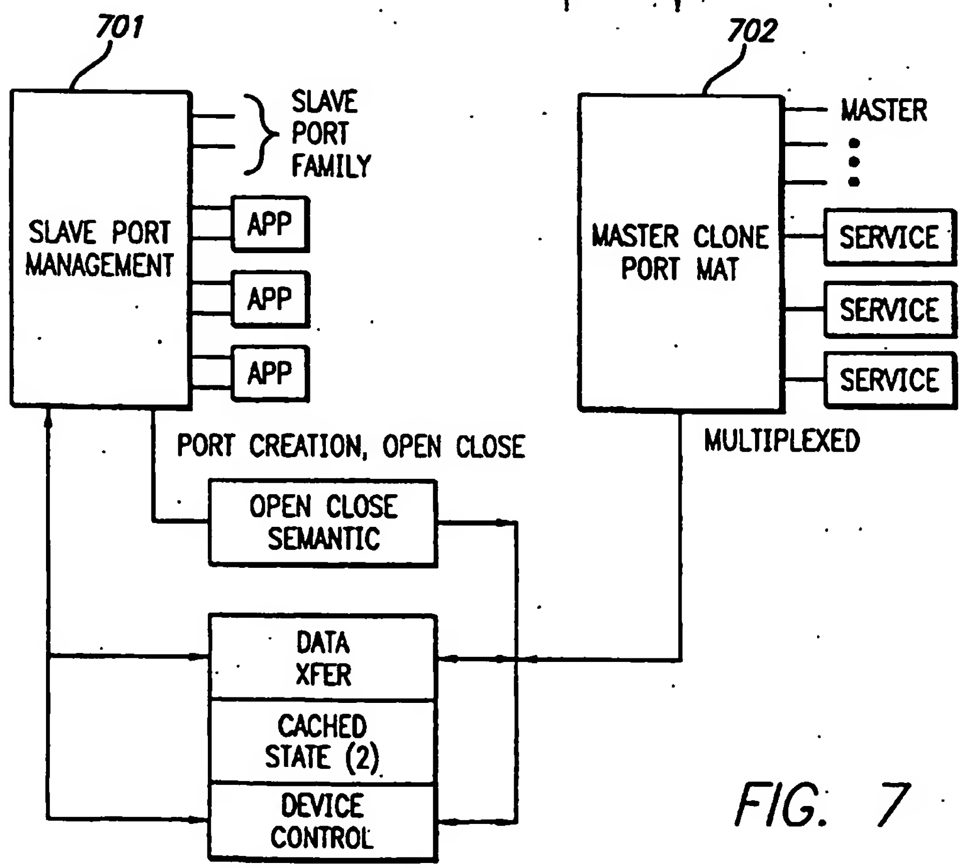
701
702
SLAVE PORT FAMILY
SLAVE PORT MANAGEMENT
APP
APP
APP
MASTER
MASTER CLONE PORT MAT
SERVICE
SERVICE
SERVICE
PORT CREATION, OPEN CLOSE
MULTIPLEXED
OPEN CLOSE SEMANTIC
DATA XFER
CACHED STATE (2)
DEVICE CONTROL

FIG. 7